Spectroscopic study of the non-yrast levels in ^{52}Cr

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Introduction

The spectroscopic study of *1f*$_{7/2}$ shell nuclei near N~28 is of significant interest because these nuclei serve as ideal candidates for description within the shell model framework. They exhibit a diverse range of nuclear phenomena, including collective behavior, band termination, and spherical-deformed shape coexistence. These phenomena have been effectively explained using advanced γ-ray spectroscopy techniques and have shown good agreement with shell model calculations.

The nucleus ^{52}Cr possesses 12 valence nucleons (4 protons and 8 neutrons) in the *1f*$_{7/2}$ shell. Numerous studies have been conducted on this nucleus using both heavy-ion and light-ion reactions. The most recent work on ^{52}Cr, populated through heavy ion induced reaction, was reported by Rajesh Kumar *et al*. [1]. In this study, the level scheme was extended up to 10 MeV, with spins reaching $J^{\pi}=13^{+}$ and investigated only the structural properties of the yrast levels of ^{52}Cr. The primary objective of the present study is to extend the level scheme of ^{52}Cr horizontally and investigate the structural properties of the non-yrast levels in ^{52}Cr. Finally, the experimental observation will be compared with the results obtained from shell model calculations to understand their microscopic origin.

Experimental Details

High-spin states of ^{52}Cr were populated via ^{51}V(^{4}He,*2np*)^{52}Cr fusion evaporation reaction. The experiment was performed using a 45 MeV alpha beam, delivered from the K-130 Cyclotron, stationed at the Variable Energy Cyclotron Centre (VECC), Kolkata. A self-supported ~12 mg/cm^2 thick natural vanadium target was used for the experiment, within which ~95% of the recoils stopped. The de-excitation of γ-rays was detected using the Indian National Gamma Array (INGA) at VECC, which was comprised of 11 Compton-suppressed clovers (6 were mounted at 90°, 3 at 125°, and 2 at 40°) and 1 LEPS (mounted at 40°) at the time of experiment. Singles and two-fold coincidence events were recorded in list mode using a PIXIE-16 based digital data acquisition system [2]. The raw data were sorted, and both angle-independent and angle-dependent symmetric and asymmetric matrices were constructed using the BiNDAS package [3]. Data analysis was carried out using INGASORT [4]. Energy calibration was performed with the radioactive source ^{152}Eu and some online gammas having energies up to 3 MeV. The relative efficiency of the clover detectors was determined using radioactive sources ^{152}Eu and ^{66}Ga.

Results and Discussions

The excited states of ^{52}Cr were investigated through coincidence relationships and relative intensity measurements using a symmetric 90° vs 90° matrix, with careful consideration given to the angular distribution of dipole and quadrupole transitions. All existing transitions were observed by putting a gate on the 1433.9 keV ground state transition (Fig. 1). We have not found any transitions coming from the levels above $J^{\pi}=13^{+}$. But several new transitions have been found, which are mostly coming from the non-yrast levels. We have placed 19 new transitions and 8 new levels in the level scheme based on their coincidence relationship and relative intensities.

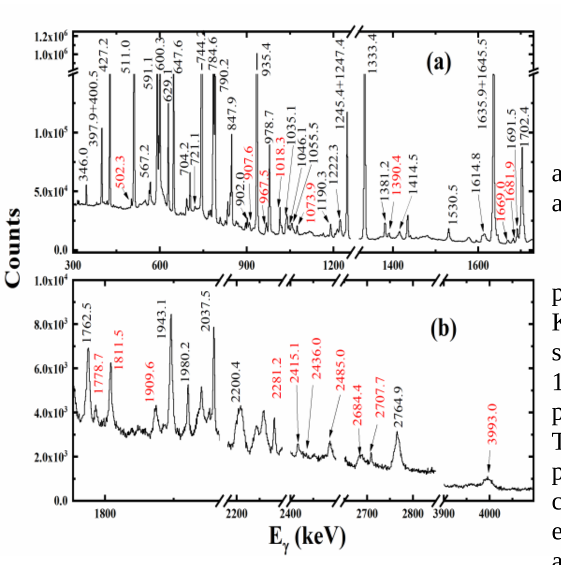

Fig. 1: Typical background-subtracted spectrum [(a) 300 to 1730 keV, (b) 1730 to 4096 keV] obtained by putting a gate on the 1433.9 keV transition. It shows all the existing (black) and new (red) transitions that belong to ^{52}Cr. The spectrum was generated from 90° vs. 90° matrix.

The spin-parity of most of the newly identified levels has been confirmed based on the results obtained from Directional correlation (DCO) and polarization (IPDCO) measurements. The DCO and IPDCO measurements could not be performed for a few new transitions due to their poor statistics. The spin and parity of a few levels were earlier assigned tentatively [1]. In the present work, we have confirmed / modified the spin and parity of those levels using their measured DCO and IPDCO values of the decay out transitions of interest.

We have observed Doppler shifted peaks for a few transitions in ^{52}Cr, as shown in Fig. 2. Lineshape analysis will therefore be carried out to measure the lifetimes of these levels.

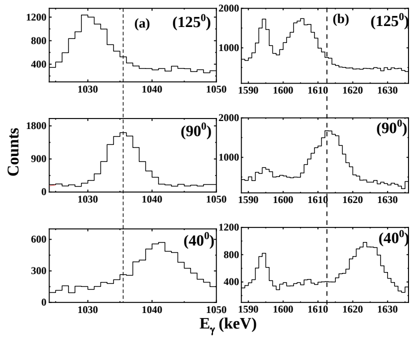

Fig. 2: Doppler shifted peaks of (a) 1035.1 and (b) 1614.8 keV transitions at three different angles.

Large basis shell model calculations were performed using the NUSHELLX code [5] and KB3GPN [6] effective interaction. The valence space consisted of the full fp major shell with $1f_{7/2}$, $1f_{5/2}$, $2p_{3/2}$, and $2p_{1/2}$ orbitals for both protons and neutrons above the ^{40}Ca inert core. The calculations were performed without any particle restrictions in the fp valence space. The calculated energies have been compared with the experimental energies and they are mostly agreed well. Now, transition probabilities, moments, spectroscopic factors, etc., will be carried out to understand the microscopic structure of the non-yrast levels of ^{52}Cr.

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